Second Midterm Exam
November 15, 2006

Print your name: 

Student ID: 

Signature: 

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Closed book; no notes, including calculator memory.

All calculations should be very short and can fit in the spaces provided. Nevertheless, you may attach additional sheets of paper if necessary. All numbers given are assumed accurate to 2 significant figures. Your answers should have no less than 2 and no more than 3 significant figures. Your exam should have 6 pages (including this cover) and 15 questions and problems.

The following constants and equations may or may not be needed:

- Coulomb’s law constant: \( k = \frac{1}{4\pi \varepsilon_0} = 9.0 \cdot 10^{-9} \text{ Nm}^2 / \text{C}^2 \).
- Permittivity of free space: \( \varepsilon_0 = 8.9 \cdot 10^{-12} \text{ F/m} \).
- Permeability of free space: \( \mu_0 = 4\pi \cdot 10^{-7} \text{ Tm/A} \).
- Electron mass: \( 9.1 \cdot 10^{-31} \text{ kg} \). Proton mass: \( 1.7 \cdot 10^{-27} \text{ kg} \). Neutron mass: \( 1.7 \cdot 10^{-27} \text{ kg} \).
- Electronic charge: \( e = 1.6 \cdot 10^{-19} \text{ C} \).
- Avogadro’s number: \( N_A = 6.0 \cdot 10^{23} \text{ mol}^{-1} \).
- Speed of light in vacuum: \( c = 3.0 \cdot 10^8 \text{ m/s} \).
- Work done by a conservative force: \( W_{a\rightarrow b} = U_a - U_b = -\Delta U \).
- Cylindrical conductor geometry: \( V(r) = \frac{\lambda}{2\pi \varepsilon_0} \ln \left( \frac{r_0}{r} \right) \), \( \vec{E}(r) = \frac{\lambda}{2\pi \varepsilon_0} \frac{1}{r} \hat{r} \), \( C = \frac{2\pi \varepsilon_0}{\ln(r_b/r_a)} \cdot L \).
- Spherical conductor geometry: \( V(r) \) and \( \vec{E}(r) \) by memory. \( C = 4\pi \varepsilon_0 \frac{r_a r_b}{r_b - r_a} \).
- Capacitors in series: \( \frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} \), and in parallel \( C = C_1 + C_2 \).
• Series resistors: \( R_{eq} = R_1 + R_2 \). Parallel resistors: \( \frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} \).

• Time constant of an RC circuit: \( \tau = RC \)

• Cyclotron frequency: \( \omega = \frac{eB}{m} \)

1. (3 pts) Two copper wires are each 2.0 m long. One wire has twice as large a cross-sectional area as the other. Which wire has a larger resistivity \( \rho \)?
   a) The thick wire.
   b) The thin wire.
   c) The resistivity is the same for the two wires.
   d) It is impossible to know without being given the shape of the cross section.

2. (3 pts) What transition occurs in iron when it is heated up through the Curie temperature (770°C)?
   a) diamagnetic to paramagnetic phase transition
   b) ferromagnetic to diamagnetic phase transition
   c) ferromagnetic to paramagnetic phase transition
   d) solid to liquid phase transition

3. (3 pts) Consider the RC circuit below. The capacitor is initially discharged, and then at time \( t=0 \) the switch is closed. Which of the following equations correctly describes the time dependence of the charge on the capacitor?
   a) \( Q(t) = CV(1 - e^{-t/RC}) \)
   b) \( Q(t) = CVe^{-t/RC} \)
   c) \( Q(t) = \frac{V}{R}(1 - e^{-t/RC}) \)
   d) \( Q(t) = CV(1 + e^{-t/RC}) \)

4. (3 pts) Which of the following equations describes correctly the time dependence of the current in the RC circuit of the previous question?
   a) \( I(t) = \frac{V}{R} e^{-t/RC} \)
   b) \( I(t) = \frac{V}{R} e^{-t/RC} \)
   c) \( I(t) = RC e^{-t/RC} \)
   d) \( I(t) = RC(1 + e^{-t/RC}) \)

5. (3 pts) In the circuit shown here with two lamps, when the switch is closed, what will happen to the brightness of lamps A and B?
   a) Both lamps will get brighter.
   b) Lamp B will get slightly dimmer while lamp A will get brighter.
   c) Lamp B will go dark while lamp A will stay the same.
   d) Lamp B will go dark while lamp A will get brighter.
   e) Lamp B will get brighter while lamp A will get dimmer.

6. (3 pts) In the circuit shown here with 3 identical ideal batteries (no internal resistance) and two identical bulbs, what happens to the brightness of the bulbs when the switch is closed?
   a) They both go dark.
   b) Bulb A remains the same while bulb B gets much brighter.
   c) Both bulbs get much brighter.
   d) Bulb A remains the same while bulb B goes dark.
   e) The brightness does not change for either bulb.
7. (3 pts) Which of the following integrals will yield the correct result for the \( z \) component of the magnetic field at point \( P \) in the figure? The wire stretches from \(-a\) to \(+a\) along the \( y \) axis, and point \( P \) is a distance \( x \) from the origin, on the \( x \) axis.

a) \[ B_z = -\frac{\mu_0 I}{4\pi} x \int_{-a}^{a} \frac{dy}{(x^2 + y^2)^{3/2}} \]

b) \[ B_z = -\frac{\mu_0 I}{4\pi} a \int_{-a}^{a} \frac{dy}{\sqrt{x^2 + y^2}} \]

c) \[ B_z = -\frac{\mu_0 I}{4\pi} a \int_{-a}^{a} \frac{y dy}{(x^2 + y^2)^{3/2}} \]

d) \[ B_z = \frac{\mu_0 I}{4\pi} a \int_{-a}^{a} \frac{y dy}{(x^2 + y^2)^{3/2}} \]

e) \[ B_z = -\frac{\mu_0 I}{4\pi} a \int_{-a}^{a} \frac{dy}{x^2 + y^2} \]

8. (3 pts) An electron moving with speed \( v \) in the \( x \) direction enters a region of constant magnetic field \( B \) in the \( z \) direction. It makes a turn of 180 degrees and exits the magnetic field region. What is the rate at which energy is transferred to the electron by the magnetic field?

a) 0
b) \( eBv \)
c) \( eBv^2 \)
d) \( eB/m \)

9. (6 pts) The circuit on the right consists of a battery, a resistor, and two identical copper wires.

a) How does the electron drift velocity at point A compare with that at point B?
   i) \( v_A = v_B \)
   ii) \( v_A < v_B \)
   iii) \( v_A > v_B \)

b) How does the electron potential energy at point A compare with that at point B?
   i) \( U_A = U_B \)
   ii) \( U_A > U_B \)
   iii) \( U_A < U_B \)

10. (4 pts) The circuit on the right has 6 identical light bulbs powered by a single battery. Rank the light bulbs in order of decreasing brightness.

a) A,E,F,C,B,D
b) A=C,B,E,F,D
c) E=F,D,B,C,A
d) A,C,B=D,E=F
e) C,A,B,D,E=F
f) A,C,B,D,F,E
g) A,B=C=D,E=F
11. (9 pnts) The following plot shows electrostatic potential contours around two identical point charges.
   a) Rank the fields at points A through C in order of decreasing electric field strength.
      i) B,C,A
      ii) A,B=C
      iii) B=C,A
      iv) C,B,A
   b) Draw electric field vectors at each of the points A, B, C, and D indicating the field direction.

   ![Diagram of electrostatic potential contours]

   c) Given that the distance between the point charges is 4.0 cm, the field magnitude at point D is approximately
      i) 30 V/m
      ii) 40 V/m
      iii) 1000 V/m
      iv) 4000 V/m
      v) 10,000 V/m

12. (3 pnts) In this circuit with 3 light bulbs, a battery, and a switch, what happens when the switch closes?
   a) Bulb A gets brighter while bulb B gets dimmer.
   b) Bulb A gets dimmer while bulb B gets brighter.
   c) Both bulbs A and B get brighter.
   d) Both bulbs A and B get dimmer.

13. (3 pnts) The drawing on the right shows a solenoid next to a straight wire carrying current into the page. The arrow represents the magnetic force on the wire. What is the direction of the current flowing through the solenoid?
   a) From left to right.
   b) From right to left.
   c) It’s not possible to tell from the information given.
14. Consider the circuit below, with battery voltage $V_0 = 12\,\text{V}$.

\begin{center}
\includegraphics[width=0.4\textwidth]{circuit.png}
\end{center}

a) (10 pts) Find the value of the current flowing through the battery after the switch has been closed for a very long time (i.e. after the capacitor is fully charged).

b) (8 pts) Find the value of the current flowing through the 6.0 ohm resistor after the switch has been closed for a very long time.

c) (8 pts) After the switch has been closed for a very long time, it is opened at time $t_0$. The voltage on the capacitor then decreases according to $V(t) = V_C e^{-(t-t_0)/\tau}$. What are the numerical values of $V_C$ and $\tau$?
15. A straight wire located at \( x = 10 \text{ cm} \) on the \( x \) axis carries 2.0 A of current in the \( z \) direction. Another straight wire located at \( y = -5 \text{ cm} \) on the \( y \) axis carries 1.0 A of current in the \(-z\) direction.

\[ \text{Diagram showing two current-carrying wires.} \]

a) (20 pts) Calculate the magnitude and direction of the magnetic field at the origin. Give the direction as an angle from the positive or negative \( x \) axis.

b) (5 pts) A particle with 2.0 g mass and a charge of +8.0 nC is at the origin at this instant in time traveling with velocity 10,000 m/s in the positive \( z \) direction (out of the page). Find the direction of the magnetic force on this particle. Give the direction as an angle from the positive or negative \( x \) axis.